Quantifying Acoustic Uncertainty due To Marine Mammals and Fish Near the Shelfbreak Front Off Cape Hatteras

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LONG TERM GOALS

The long term goals of our work on acoustic uncertainty due to fish and marine mammals are to: 1) understand the nature of low-to-medium frequency (100-2000 Hz) acoustic scattering (specifically reverberation and attenuation) by fish schools and larger marine mammals, 2) advance our acoustic methods of quantitatively imaging fish schools and tracking vocalizing marine mammals, and 3) understand the correlation between the detailed physical oceanography and the biology and acoustics.

OBJECTIVES

Our primary objectives this year were: 1) perform analysis of our "year one" survey cruise data and especially our "year two" major experiment data (taken off Cape Hatteras, N.C. to measure the acoustics, biology, and physical oceanography of fish schools) and 2) then compare the year one and year two results, as this comments on the variability in the ecosystem.

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APPROACH

The basic tools/methodology employed in our "year two" major cruise consisted of a combination of: 1) an AUV mounted acoustic source, 2) moored multi-element SHRU acoustic receiver arrays, 3) a shipboard acoustic resonator, 4) fish-attraction devices (FAD's), 5) a three-AUV fish-field mapping effort (employing sidescan sonar plus optics) and 6) ScanFish, ADCP, and moored sensor oceanographic field mapping. The day-to-day experimental plan was to: 1) survey the oceanography at night to find the shelfbreak front and other features that might attract fish, 2) survey for fish during the day based on the oceanography survey results, 3) given a good fish population "target", deploy the SHRU receivers and FAD's and perform REMUS vehicle operations to both map the fish school and examine its 500-2000 Hz scattering characteristics.

Our post cruise (year 3) approach is simply to simultaneously analyze the acoustic, biologic, and physical oceanographic data to see the correlations between the three areas.

WORK COMPLETED/ACCOMPLISHMENTS

The major cruise, which went from May 13-May 30, 2012, was very productive overall, though the results in some cases have significant variability comparing to the pilot cruise and climatological data (which was very interesting.) Thus our analysis efforts this past year concentrated on the analysis of the 2012 data set.

A suite of signal processing programs and a Hamiltonian acoustic ray program have been developed to allow acoustic data extraction, pulse-compression processing, frequency spectrum analysis and calculation of acoustic eigenrays. These programs were used this year to analyze the 2012 acoustic data, and we now have some solid initial results that show the attenuation and scattering from the fish. These were presented at an Acoustical Society of America meeting last year, and archived in POMA. Further work is needed to produce a full peer-reviewed manuscript. Specific results are discussed in the next section.

RESULTS

We will relate some interesting results in the acoustics and physical oceanography in this report, with the results from the biological (fish field) mapping being deferred to next year's report.

Acoustically, we were interested in looking at the attenuation and scattering due to fish schools. In Figures 1, we show images of our REMUS sound source vehicle both inside a school of Blue Runner fish and also a short ways outside of the school. These images taken by GoPro video correlate to our acoustic tracks, and to the receptions seen at the moored SHRU receivers. In the acoustic data record, we see both the attenuation (when in the school) and the scattering (outside the school, and in the immediate vicinity.) Figure 2 shows the attenuation part of the acoustic record more closely. We see that the attenuation due to the school can be very large (up to 18 dB maximum), and also affects the first arrival the most strongly. In Figure 3, we show the scattered arrivals. These appear later in the record (i.e. late arrivals), and can be due to a number of effects, which we are currently sorting out.

Oceanographically, the hydrographic data from the continental shelf north of Cape Hatteras in May 2012 had warm anomalies relative to prior observations in the region. We examined the regional response of the continental shelf using a combination of National Data Buoy Center sea surface

temperature time series along with other hydrographic data (Chen et al., 2013). The warming was due to positive (warm) air-sea flux anomalies during late autumn and early winter that substantially reduced the winter cooling rate from Cape Hatteras to the Gulf of Maine (Figure 4). The warm anomalies persisted for approximately 6 months through this region, with average anomalies of roughly 2 Degrees C. Short-term fluctuations included temperature anomalies of up to 6 Degrees C. near Cape Hatteras.

Examination of atmospheric forcing revealed that the Jet Stream shifted northward during this time period, which explains the large-scale range of the temperature anomalies over the continental shelf and also the in-phase fluctuations between the four National Data Buoy Center sea surface temperature values.

IMPACT/APPLICATIONS

The impact of our experiment should be: 1) an increased understanding of the scattering of sound through fish schools, which can help discriminate fish schools as "false targets" for sonars, 2) improved methods for mapping fish populations and schools, which is important in that the "biological field" is often an unknown for both experimental studies and Navy applications, and thus could be quantified, and 3) a beginning understanding of how climate change may be affecting shallow water acoustics, both through the fish, and perhaps more importantly, through the ocean temperature field.

TRANSITIONS

Being able to model the acoustics of fish schools will allow them to be discriminated against as false targets ion sonar systems. Also, in the case of larger shoals, the effective attenuation due to the fish can be estimated. Further, the ability to incorporate fish and climate change into Navy models could be a useful payoff.

RELATED PROJECTS

This work is related to the work of K. Benoit-Bird and her work off the west coast of the United States as well as T. Stanton and D. Greenbaum who are working on theoretical aspects of fish school behavior and the scattering of sound within fish schools. This work also relates to efforts to quantify uncertainty in acoustic propagation from the Quantifying, Predicting, and Exploiting Uncertainty DRI.

PUBLICATIONS

A. Recent Publications (refereed)

K. Chen, G. Gawarkiewicz, S. Lentz, and J. Bane. Diagnosing the warming of the Northeast U.S. coastal ocean in 2012. J. of Geophysical Research-Oceans (2013) [Peer reviewed, in revision.]

B. Recent Publications (non-refereed)

A.E. Newhall, J. F. Lynch, Y.-T. Lin, T. Grothues, and G.G. Gawarkiewicz, "Scattering and reverberation from fish schools in the 500–1500 Hertz band," *POMA*, vol. 19, pp. 005-028 (2013)

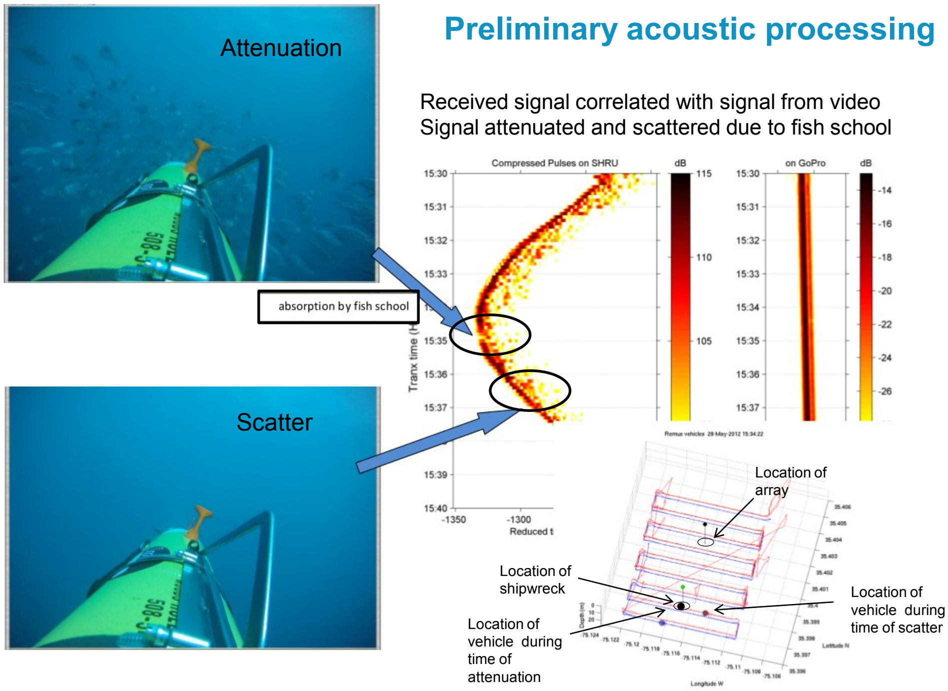

Figure 1. An example of the acoustic attenuation and scattering seen in our experiment as the REMUS AUV transits near a fish school.

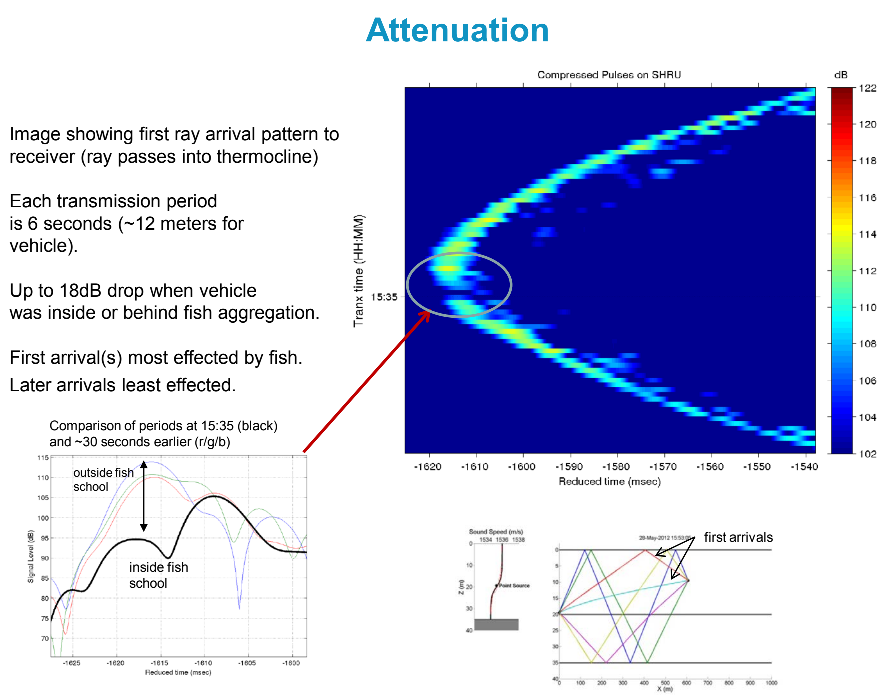

Figure 2. A clear example of the attenuation seen with the vehicle inside the fish school or behind it (relative to the receiver.)

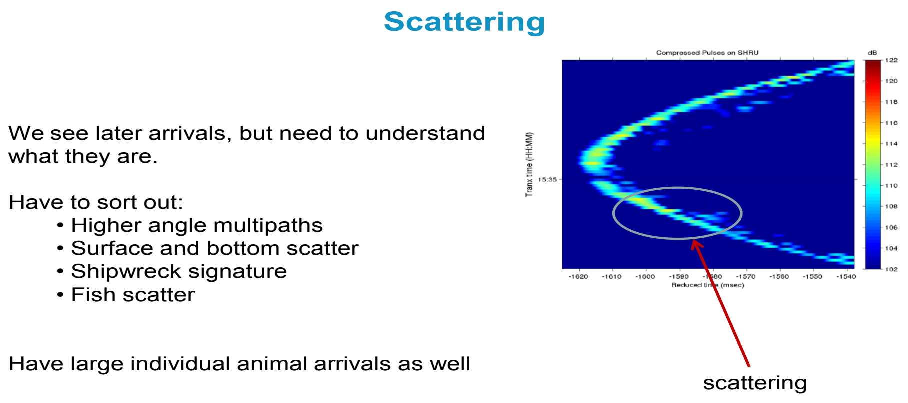

Figure 3. An example of the scattering seen from the fish school.

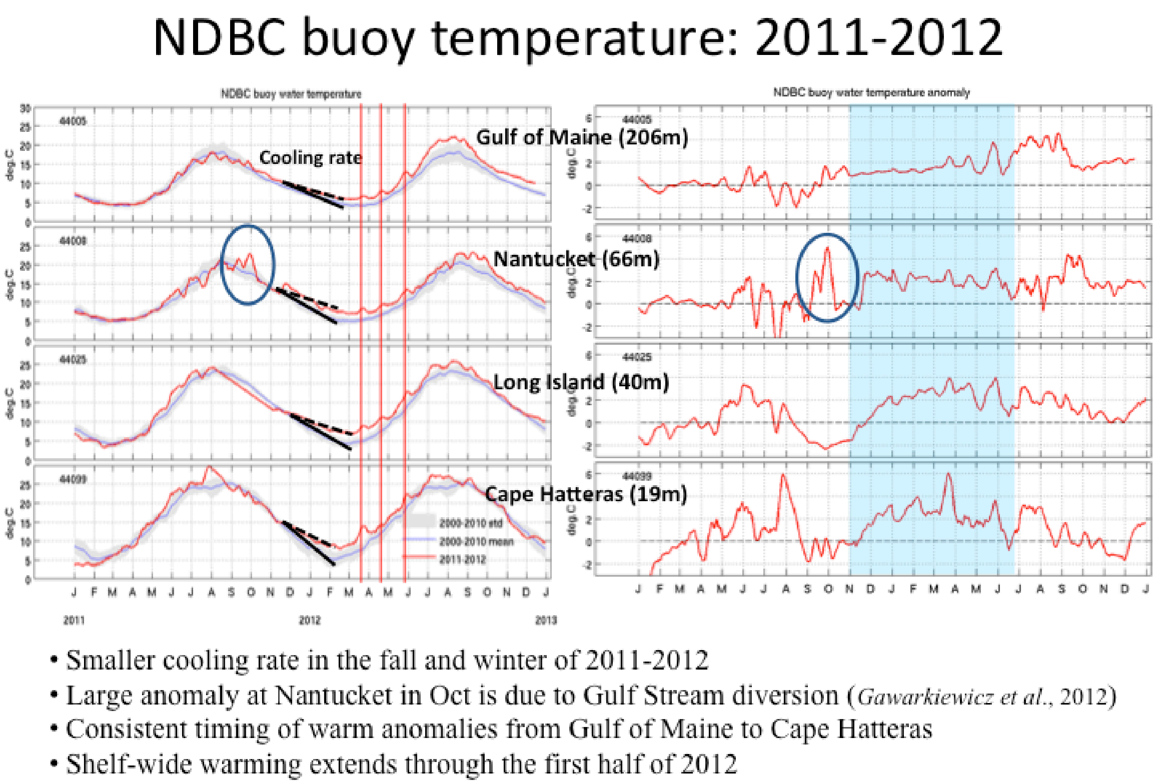

Figure 4. Temperature anomalies in the Mid Atlantic Bight region.